DOCUMENT RESUME

ED 123 112 SE 020 830

AUTHOR Quinn, Mary Ellen; Kessler, Carolyn
TITLE The Relationship Between Science Education and Language Development.
PUB DATE Apr 76
NOTE 24p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, California, April 19-23, 1976)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS Activity Learning; Cognitive Ability; *Educational Research; Elementary Education; *Elementary School Science; *Language Development; *Language Skills; Learning Activities; *Science Activities; Science Education
IDENTIFIERS Research Reports

ABSTRACT

Reported is a study on hypothesis formation related to the possible relationship between skills involved in acquiring language and those in an activity-based science program. The data were analyzed by both a science educator and a linguist for possible correlation between the cognitive ability to formulate good hypotheses and the ability to produce increasingly more complex syntatic structures. The paper reports evidence from other studies indicating that children involved in one of the newer activity courses tend to improve in language art skills. Two intact sixth grade classes participated in the study; one of which served as the control. The treatment consisted of 12 film sessions and 6 discussion sessions, all related to inquiry development and instruction on how to formulate hypotheses. It was evidenced that the students involved in the treatment did indeed improve in their ability to hypothesize, a cognitive skill considered central to the learning of science. Among the theoretical implications of the study is one that challenges the view that an individual who is successful in science is generally not as proficient in language-centered activities, or the converse. Evidence of the studies reflects this. (Ed)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

SCOPE OF INTEREST NOTICE

The ERIC Facility has assigned this document for processing to: SE FL

In our judgement, this document is also of interest to the clearinghouses noted to the right. Indexing should reflect their special points of view.

ED123112

THE RELATIONSHIP BETWEEN SCIENCE EDUCATION AND LANGUAGE DEVELOPMENT

Mary Ellen Quinn, Ed.D.

Edgewood Independent School District
San Antonio, Texas

Carolyn Kessler, Ph.D.

University of Texas at San Antonio

Paper presented at the annual meeting of the American Educational Research Association, April 1976.

San Francisco, California

SE 020 830

THE RELATIONSHIP BETWEEN SCIENCE EDUCATION AND LANGUAGE DEVELOPMENT

Mary Ellen Quinn, Ed.D.
Edgewood Independent School District
San Antonio, Texas

Carolyn Kessler, Ph.D.
University of Texas at San Antonio

There is increasing evidence of a close relationship between the skills involved in acquiring language and those experienced in an activity-based science program. Data gathered during an experimental study of hypothesis formation was analyzed by both a science educator and a linguist for possible correlation between the cognitive ability to formulate good hypotheses and the ability to produce increasingly complex syntactic structures. This paper reports that a positive correlation exists between scientific hypotheses formulated by sixth grade children and the level of syntactic complexity of the written language used to express those hypothesis.

THE RELATIONSHIP BETWEEN SCIENCE EDUCATION AND LANGUAGE DEVELOPMENT

1.0 Introduction

With increasing frequency studies in the acquisition of language are moving from an emphasis on the acquisition of specific forms to investigations of the underlying cognitive processes governing the ability to acquire the systems of language. In ways not yet understood, cognitive mechanisms of categorization, interrelation or transformation operate on linguistic data that come to the child. Through hypothesis formation and hypothesis testing, the child constructs the set of rules accounting for the grammar of his language. As more refined hypotheses are generated, the child's grammar steadily progresses toward that of the adult's. Although the onset of two-word syntactic structures is generally about 18 months of age, the upper limits of the age at which the adult grammar is fully encoded have not yet been determined. Chomsky (1969) has demonstrated that monolingual English-speaking children even at age 10 have not developed some of the more complex structures of English. Kessler (1971) in a study conducted with bilingual 6 to 9-year-old children also found that the upper limit identifying the equivalent for the adult grammar had not been attained by the oldest children in the group.

Studies demonstrating that children well into the school years are still in developmental stages of language acquisition

closely parallel Piaget's theory of cognitive development. Tremaine (1975) found that the comprehension of syntactic structures in bilingual children is closely correlated with the development of Piagetian operational intelligence. Kessler's study also gives evidence from bilingual Italian-English speaking children that the comprehension of an interrelated set of syntactic structures follows a maturational sequence much like that of operational thought. In studying the acquisition of specific linguistic transformations in children, Ingram (1975) points out that the child's linguistic development in the ability to take into account relationships between sentences is directly analogous to his cognitive development between ages 3 and 12. Studies conducted by Ferreiro and Sinclair (1971), from a Piagetian perspective, further illustrate that the child's ability to perform certain linguistic operations is closely related to cognitive development. And cognitive development crosses all areas of intellectual development.

The purpose of the study reported in this paper is to investigate the relationship between language development and an inquiry-approach to science education. Given the theory current in developmental psycholinguistics that language acquisition results from a series of evolving hypotheses, tested and either accepted or rejected, it seems reasonable to assume that children specifically taught to improve the quality of their hypotheses formulated in a science class should give evidence of progressing into higher levels of language development. Of

course, the formation of hypotheses is but one aspect of science teaching.

Among investigators who have examined the relationship between science teaching and language acquisition, Rowe (1978), McGlathery (1968), Ayers and Mason (1969), Huff and Languis (1973) have all found that young children involved in an activity-based science course make considerable language gains, even scoring higher in standardized readings tests than their non-science peers. Recently, various science programs have been set up with their contributions to the development of language skills in mind. Among theses are those of the All Indian Pueblo Council-Lawrence Hall of Science Project under the direction of Herbert Thier (1975) and the Hillsborough County Public Schools (1974). None of these studies, however, have focused on the role of hypothesis formation in science teaching and its relationship to the development of language. The focus of this paper is to examine this relationship.

2.0 Methodology

The framework for studying the ability of children to form hypotheses is set forth in a study by Quinn (1971), which evaluated a method for teaching hypothesis formation to sixth grade children. This study concluded that under the conditions described in that study, hypothesis formation can be taught, that the quality of the hypotheses elicited can be measured with the Hypothesis Quality Scale developed by Quinn, that the ability to hypothesize is correlated with the intelligence,

overall grade point average, reading ability, and sex of the student. The evidence from this investigation refutes the position that hypothesis formation is intuitive and cannot be taught.

2.1 Sample

Two intact sixth grade classes of 32 students each participated in the study. The classes were from a Catholic school in Warminster, Pennsylvania, an upper middle class suburb of Philadelphia. One class served as the control, the other as the treatment group.

2.2 Treatment

The treatment consisted of 12 film sessions and 6 discussion sessions, each session 40 minutes in length. In the film or problem-presentation session, the investigator showed one of the film loops of the Inquiry Development Program in Physical Science developed by J. Richard Suchman (1962). Each 3-minute film loop depicts a single physical science problem. Procedures followed in conducting the film sessions were: (1) showing the film; (2) questioning the students briefly to ascertain that they recognized the problem; (3) informing the students that they could gather information for solving the problem by asking yes/no questions of the teacher; (4) reshowing the film with a brief questioning period after it; (5) having the children write as many hypotheses as they could in a rigorously controlled 12-minute period. The papers were then collected and scored on two criteria: the Hypothesis Quality Scale developed by Quinn

and the Syntactic Complexity Formula developed by Botel, Dawkins and Granowsky (1973).

Following each set of two film sessions, one of the investigators conducted a discussion session which focused on teaching the children how to formulate good hypotheses. They were taught to recognize logical contraries, distinguish between statements with an empirical base from those with a nonempirical base, report some of the physical properties of the objects observed in the film,,report which conditions varied during their observation of the science problem presented on film and the sequence of the variation, make inferences about their observations, state empirically-based relationships between observations and inferences, propose tests for the hypotheses they formulated.

During each of the discussion sessions, the investigator interacted with the children by asking what they observed, inferred, and what changes in physical conditions took place during the film. Both statements given by the children and some of the hypotheses they had written during the film sessions were written on the blackboard. The investigator then applied the Hypothesis Quality Scale to these statements to show the children how to judge their own hypotheses and how to make use of their observations and inferences to generate ones of higher quality. Children in the treatment group consequently learned to distinguish between a 0-value hypothesis as 'Magic did it' from a 5-value one, the highest score on the scale, as 'I could

test my idea by putting several little bottles with different amounts of water in them in a tub and then seeing which ones would sink.'

At the end of the treatment, three additional film sessions were presented to elicit hypotheses that were scored in order to obtain the criterion variable of the treatment group. The same films were presented to the control group to elicit hypotheses for the criterion variable for that group. The hypotheses generated under these conditions provide the raw data for the present study.

2.3 Hypothesis Quality Scale

In this study an hypothesis is defined as a testable explanation of an empirical relationship among variables in a given problem situation. To be an acceptable hypothesis, a statement must satisfy at least one of the following criteria: (1) it makes sense; (2) it is empirically based; (3) it is adequate; (4) it is precise; (5) it states a test. Based on these criteria, a Hypothesis Quality Scale was constructed according to which student-generated hypotheses were scored. (Quinn and George 1975, 290)

INSERT TABLE 1

To determine the reliability of the Hypothesis Quality Scale, a set of 50 hypotheses taken from those written by the

TABLE 1

HYPOTHESIS QUALITY SCALE

Score	Criterion
0	No explanation, such as, a non-sense statement, a question, an observation, a single inference about a single concrete object.
1	Non-scientific explanation, such as, '...because it's magic' or '...because the man pushed a button.'
2	Partial scientific explanation, such as, incomplete reference to variables, a negative explanation, an analogy.
3	Scientific explanation relating at least two variables in general or non-specific terms.
4	Precise scientific explanation, a qualification and/or quantification of the variables.
5	Explicit statement of a test of an hypothesis. (An inference is made there that the child who states a test is also able to adequately and precisely hypothesize.)

sixth grade children in the study were given to three science educators who then were asked to score each using the scale given. The Nash-Beyers (Winer 1962) computer program for interjudge reliability gave an unadjusted reliability coefficient of 0.94, establishing the reliability of the scale.

2.4 Syntactic Complexity Formula

The Botel-Dawkins-Granowsky measure of syntactic complexity was selected from among others because of the theoretical basis on which it was established and because of the ease with which

it can be used by the non-linguist. The formula is derived from transformational-generative grammar theory. Furthermore, it takes into account language development and performance studies which consider the frequency of usage of structures in children's oral and written language as well as experimental data on children's processing of syntactic structures. In applying the formula, syntactic structures are assigned weighted scores ranging from 0 to 3.

One significant feature of the Botel-Dawkins-Grannowsky formula is that syntactic maturity or complexity is a function of specific structures rather than sentence length. As is well-documented in the literature on developmental psycholinguistics, a long sentence with extensive 'and' conjunctions reflects an earlier stage of language development than one in which complex embeddings resulting in shorter sentences are observed. For example, 'I have a cat and her name is Boots' is less complex than 'I have a cat named Boots.' The linguistic transformations generating the latter sentence are taken into account in the formula used in this study.

In determining the reliability of the Syntactic Complexity Formula the same set of 50 hypotheses used in determining the interjudge reliability of the Hypothesis Quality Scale was given to four judges, three of whom were language educators but non-linguists. The fourth judge was a linguist. The Nash-Beyers computer program for interjudge reliability gave an unadjusted reliability coefficient of 0.98.

3.0 Results

In a more extensive study with sixth grade children, Quinn (1971) tested the research hypothesis that there is a difference between the quality of hypotheses formulated by students who received instruction in formulating hypotheses and those who did not. Through a two-by-two factorial design to compare control and treatment groups, statistical results from an analysis of coveriance demonstrated that treatment was effective at the 0.001 level of significance. In other words, sixth grade students involved in the study did indeed improve in their ability to hypothesize. They had improved in a cognitive skill considered central to the learning of science.

In this related study, the focus is on the correlation between the quality of the hypotheses generated by the treatment and nontreatment groups and the level of syntactic complexity of the written hypotheses. The central research hypotheses tested, therefore, were:

1) There is a difference between the level of syntactic complexity of hypotheses formulated by the treatment group and those formulated by the control group.

2) There is a positive correlation between the quality of hypotheses scores and the level of syntactic complexity scores for the written language used to express the hypotheses.

This study also investigates possible correlation between both the hypothesis quality scores and syntactic complexity scores with: (1) intelligence quotient scores as measured by

Otis Quick-Scoring Mental Ability Test, Beta, Form FM; (2) reading scores as measured by Part III of the Pupil Progress Series, Diagnostic Reading Test; (3) overall grade-point averages.

In summary, five variables are considered for the control and treatment groups: (1) hypothesis quality, (2) syntactic complexity of the hypotheses formulated, (3) intelligence quotient, (4) reading, and (5) grade-point average. Table 2 gives the means and standard deviations for both the treatment and non treatment groups.

TABLE 2

MEANS AND STANDARD DEVIATIONS

Variable	Control		Treatment	
	Mean	SD	mean	SD
hypothesis quality	25.4	11.4	53.3	21.5
syntactic complexity	52.6	25.4	130.0	45.5
intelligence quotient	108.9	21.7	110.7	10.8
reading	67.2	15.8	70.1	12.0
grade-point average	79.2	15.5	80.2	6.1

For the two groups, closely matched for IQ and reading scores, the means for hypothesis quality scores and syntactic complexity are markedly higher for the group which received instruction in science focusing on problem-solving situations. The first research hypothesis that there is a difference

between the level of syntactic complexity of hypotheses formulated by the treatment group and those of the nontreatment group can be accepted. Mean scores indicate treatment in hypothesis formation does indeed result in written language scored at a much higher level of syntactic complexity.

Correlation matrices examine the relationship between the quality of hypothesis scores and the level of syntactic complexity of the hypotheses. Table 3 gives the correlations for the control group for the five variables considered: (1) hypothesis quality (HYPO), (2) syntactic complexity of the written language (LANG), (3) reading scores (READ), (4) intelligence quotient (IQ), and (5) grade-point average (GPA).

TABLE 3

CORRELATION MATRIX FOR THE CONTROL GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.87	0.62	0.57	0.53
LANG		1.00	0.55	0.51	0.52
READ			1.00	0.88	0.89
IQ				1.00	0.95
GPA					1.00

The correlation coefficient of 0.87 between the quality of hypotheses formulated and the level of syntactic complexity used to express them in the written language is at the 0.001

level of significance.

Table 4 gives the corresponding correlation matrix for the treatment group.

TABLE 4

CORRELATION MATRIX FOR THE TREATMENT GROUP

	HYPO	LANG	READ	IQ	GPA
HYPO	1.00	0.71	0.44	0.51	0.65
LANG		1.00	0.57	0.53	0.68
READ			1.00	0.74	0.70
IQ				1.00	0.84
GPA					1.00

For the treatment group as well, the correlation coefficient of 0.71 for hypothesis quality and syntactic complexity is significant at the 0.001 level. The slightly lower Pearson product moment correlation coefficient for the treatment group is undoubtedly attributable to the scoring procedures used in determining hypothesis quality and syntactic complexity. The scores of 0 through 5 for the Hypothesis Quality Scale are not equal interval scores. The scoring procedure for assessing syntactic complexity is open-ended. In other words, the cumulative score for the syntactic complexity of an hypothesis has no fixed upper limit. It is the sum of the various linguistic structures, scored from 0 through 3, used to express the hypotheeis.

Nevertheless, it is evident that there is a positive correlation between the quality of hypotheses students generated in a science class and the level of syntactic complexity of the language used to formulate the hypotheses. The second research hypothesis, therefore, can be accepted.

4.0 Discussion

Even without applying the Botel-Dawkins-Granowsky formula, it is readily apparent that changes have occurred in the syntactic complexity of the following examples of hypotheses formulated at the end of lesson one compared with those at the end of the treatment, lesson twenty-one.

1) After lesson one Helene wrote, 'Because the one man wanted to show off.'

   After lesson twenty-one she wrote, 'I could do the thing by getting a stick, make a grove for the string, this time get marbles and let them go.'

2) At the end of lesson one Eddie wrote simply, 'The one guy was weak.'

   After the eight-week period of science experiences, he constructed the following complex structure with multiple embeddings, 'I'm going to get a couple of small balls, put them each on a piece of string with a stand, swing them and see if the other balls will react equal.'

As the hypotheses improved in quality, so too did the level of linguistic complexity increase. From this, the question arises as to why science instruction appears to facilitate language development in children. While high interest and motivation may be significant affective factors, which do play a role in language acquisition (Schumann 1975), they alone would not seem to account for the close relationship between hypothesis

formation in inquiry-approach science curricula such as the Science Curriculum Improvement Study (SCIS) and language development.

Language involves the expression of meaning, which finds its origin in the conceptualization of a situation. The sentence represents a certain conceptual structure manifested externally either in the spoken or written language. To move from conceptual structure to external or surface manifestation, three subsystems of language are involved: semantic, syntactic, phonological. The rules of these components constitute the grammar of a language. In order to acquire the rules of grammar, the child must be able to recognize the kinds of events which are encoded in language. And he must be able to process this information linguistically through all three linguistic systems.

Slobin (1973) points out that the pacesetter in linguistic growth is the child's cognitive growth. If one follows the developmental progression of a young child both from the standpoint of language acquisition and cognitive development, it can be observed that the pre-operational child, in Piagetian terms, cannot act on his language to the degree that the concrete operational child can when he performs complex transformations requiring reversible operations. Tremaine (1975) found, through a factor analysis of 22 variables and an analysis of covariance of her data, that the same abilities are involved in the comprehension of syntax and in operational thought. It is also critical to note that the conditions under which language is

acquired require a meaningful situation where the processes of hypothesizing, experimenting, and discovering can take place. Progression in language development reflects progression in the capacity to experience these processes.

Among science educators who have looked at the effects of science instruction on language are Rowe (1970) and Ayers and Ayers (1973). Rowe found that the amount of student-initiated, content-relevant speech in 10 Harlem classrooms was 200 to 500 percent higher during science classes than during language arts sessions. Ayers and Ayers found in their study of young kindergarten-age children that early science experiences as those of Science - A Process Approach (SAPA) help logical thinking to develop.

What becomes evident, then, is that researchers both in psycholinguistics and in science education are arriving at similar findings and reaching similar conclusions. Meaningful situations, such as activity-based, inquiry-oriented science programs, facilitate language development.

If language is considered from a broader base than syntactic complexity and science inquiry skills are seen as involving more than hypothesis formation, the chart given in Table 5 may give insights into the cognitive processes involved in science education and language development.

INSERT TABLE 5

Central to the chart are three steps in a cognitive process:

TABLE 5

NATURAL SCIENCE AND LANGUAGE RELATIONSHIPS

Natural Science		Language
Observing by: seeing hearing smelling feeling tasting Recording Measuring	INPUT DATA COLLECTION	Listening Experiencing Reading Looking Practicing
Classifying Graphing Contrasting Separating variables Inferring	DATA PROCESSING	A cognitive process in which linguistic data is organized within the brain
Predicting Hypothesizing Experimenting/ Testing hypotheses Interpreting	DATA USE OUTPUT	Discovery of a linguistic system Understanding the meaning of data

(1) data collection, essentially a way of providing an input of facts into the brain; (2) data processing, a mental activity during which the brain organizes or reorganizes the input into a highly individual scheme that will allow the individual to assimilate and adapt the input; (3) data use, the output or end product of cognition. Of course, that output can then become input, providing a cyclic process.

The inquiry skills of natural science on the left side of the chart are familiar to science educators. For instruction in science, the input of data collection involves observing, measuring, recording observable physical data. The data collected then undergo the processes of classifying, graphing, contrasting, separating variables and inferring. For the science learner as well as the professional scientist, data use can involve such processes as predicting, hypothesizing, experimenting or testing hypotheses, and interpreting.

On the right hand side of the chart, processes involved in language acquisition and language use are related to the same underlying processes as those involved in the observation and interpretation of physical data. When the child listens to language or reads, he is also involved in data collection. Very early in life he learns to process linguistic data as he moves through the various stages of language acquisition from babbling to one and two-word utterances, to the early sentence stage and later to the complex transformational use of linguistic structures. The cognitive processes that allow the child to construct the grammar of his language are comparable to the data processing

rules of science - categorizing, separating variables, inferring. From this, he hypothesizes, tests the hypotheses, reorganizes his grammar. Data use, then, includes a discovery of a system, the structure of a language, a set of rules that allows the child to connect meaning with what he has heard or read.

In summary, the evidence from this study indicates a direct correlation between the ability to generate scientific hypotheses and language development. As children learn to improve the quality of the hypotheses generated to solve a science problem, the complexity of the language structures used to express those hypotheses increases. Hypothesizing is a cognitive process. It appears then that the link between the formation of scientific hypotheses and language development is cognitive development. Science problem-solving activities and language acquisition involve at least some of the same organizing principles of cognition. If hypothesis formation is correlated with cognitive development, as conceptualized by Piaget, for example, and cognitive development is correlated with language acquisition, then it is reasonable to conclude that hypothesis formation and language development are logically related. As conceptual development takes place in the child, one may expect a facilitating interaction between the ability to hypothesize and the level of language development. The data from this study indicate that this interaction does occur.

5.0 Implications

The findings of this study have implications for education

from a wide range of standpoints. If young children involved in a science activity program, making use of the inquiry or process approach, generate more complex syntactic structures, one may expect these same children to read better, to achieve better in any language-based activity than children who have not had a similar science experience. Reading, in other words, need not be separated out from the teaching of other content areas in the curriculum. Furthermore, since a science curriculum which facilitates conceptual development in turn facilitates language development, the role of science education may be a crucial one in bilingual programs, assisting children in the development of their two languages. Instead of actually teaching the structure of a language directly, making experiences available, such as the type of science experience presented in this study, will provide the conditions under which language acquisition is facilitated. Language structures clearly do develop in experience-based instruction.

Among the theoretical implications of this study is one which challenges a popular view that an individual who is very successful in science is generally not as proficient in language-centered activities, or the converse. From the evidence here, it appears that both science and language activities draw on the same cognitive base. It may be expected, therefore, that, all other factors controlled, an individual can have similar proficiency in both the processes of language and science.

REFERENCES

Ayers, Jerry B., and Mary N. Ayers. 1973. Influence of SAPA on kindergarten children's use of logic in problem solving. School Science and Mathematics 73:768-771.

Ayers, Jerry B., and George Mason. 1969. Differential effects of Science - A Process Approach upon change in Metropolitan Readiness Test scores among kindergarten children. The Reading Teacher 22:435-439.

Botel, Morton, John Dawkins, and Alvin Granowsky. 1973. A syntactic complexity formula. In Assessment Problems in Reading, W.H. MacGinitie, ed. Neward, Del: International Reading Association.

Botel, Morton, and Alvin Granowsky. 1973. A formula for measuring syntactic complexity. Elementary English 49:513-516.

Chomsky, Carol. 1969. The Acquisition of Syntax in Children from 5 to 10. Cambridge, Mass.: M.I.T. Press.

Ferreiro, Emilia, and Hermine Sinclair. 1971. Temporal relations in language. International Journal of Psychology 6:39-47.

Huff, Phyllis, and Marlin Languis. 1973. The effects of the use of activities on SAPA on the oral communication skills of disadvantaged kindergarten children. Journal of Research in Science Teaching 10:165-173.

Ingram, David. 1975. If and when transformations are acquired by children. In Georgetown University Round Table on Languages and Linguistics 1975. Edited by Daniel P. Dato. Washington, D.C.: Georgetown University Press, 99-127.

Kessler, Carolyn. 1971. The Acquisition of Syntax in Bilingual Children. Washington, D.C.: Georgetown University Press.

McGlathery, G.E. 1968. An assessment of science achievement of five and six-year-old students of contrasting socio-economic backgrounds. ERIC Report ED 026 271.

Piaget, Jean, and B. Inhelder. 1969. The Psychology of the Child. New York: Basic Books.

Quinn, Mary Ellen. 1971. Evaluation of a Method for Teaching Hypothesis Formation to Sixth Grade Children. Doctoral thesis. Philadelphia: University of Pennsylvania.

Quinn, Mary Ellen and Kenneth D. George. 1975. Teaching hypothesis formation. Science Education 59:289-296.

Rowe, Mary Budd. 1970. Science and soul: some musings on fate control. Teachers College Mimeographed Report, Columbia University, New York City.

Schumann, John H. 1975. Affective factors and the problem of age in second language acquisition. Language Learning 25: 209-235.

Slobin, Dan. 1973. Cognitive prerequisites for the development of grammar. In Studies of Child Language Development. Edited by C. Ferguson and D. Slobin, 175-208. New York: Holt.

Suchman, J. Richard. 1962. The Elementary School Training Program in Scientific Inquiry. University of Illinois Press.

Tremaine, Ruth. 1975. Syntax and Piagetian Operational Thought. Washington, D.C.: Georgetown University Press.

Winer, B.J. 1962. Statistical Principles in Experimental Design. Chicago: McGraw Hill.